EPA/NSF ETV PROTOCOL

PROTOCOL FOR EQUIPMENT VERIFICATION TESTING OF VOLATILE ORGANIC CHEMICAL REMOVAL

Engineering and Research Services
NSF International   Ann Arbor, Michigan

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PROTOCOL FOR EQUIPMENT VERIFICATION TESTING
OF VOLATILE ORGANIC CHEMICAL REMOVAL
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NSF INTERNATIONAL

Mission Statement:
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NSF International (NSF) is an independent not-for-profit organization. For more than 52 years, NSF has been in the business of developing consensus standards that promote and protect public health and the environment and providing testing and certification services to ensure manufacturers and users alike that products meet those standards. Today, millions of products bear the NSF Name, Logo and/or Mark, symbols upon which the public can rely for assurance that equipment and products meet strict public health and performance criteria and standards.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Throughout its history, the U.S. Environmental Protection Agency (EPA) has evaluated technologies to determine their effectiveness in preventing, controlling, and cleaning up pollution. EPA is now expanding these efforts by instituting a new program, the Environmental Technology Verification Program---or ETV---to verify the performance of a larger universe of innovative technical solutions to problems that threaten human health or the environment. ETV was created to substantially accelerate the entrance of new environmental technologies into the domestic and international marketplace. It supplies technology buyers and developers, consulting engineers, states, and U.S. EPA regions with high quality data on the performance of new technologies. This encourages more rapid availability of approaches to better protect the environment.

ETV's Package Drinking Water Treatment Systems Pilot Project:
Concern about drinking water safety has accelerated in recent years due to much publicized outbreaks of waterborne disease and information linking ingestion of high levels of disinfection byproducts to cancer incidence. The U.S. EPA is authorized through the Safe Drinking Water Act to set numerical contaminant standards and treatment and monitoring requirements that will ensure the safety of public water supplies. However, small communities are often poorly equipped to comply with all of the requirements; less costly package treatment technologies may offer a solution. These package plants can be designed to deal with specific problems of a particular community; additionally, they may be installed on site more efficiently---requiring less start-up capital and time than traditionally constructed water treatment plants. The opportunity for the sales of such systems in other countries is also substantial.

The U.S. Environmental Protection Agency (EPA) has partnered with NSF, a nonprofit testing and certification organization, to verify performance of small package drinking water systems that serve small communities. It is expected that both the domestic and international markets for such systems are substantial. EPA and NSF have formed an oversight stakeholders group composed of buyers, sellers, and states (issuers of permits), to assist in formulating consensus testing protocols. A goal of verification testing is to enhance and facilitate the acceptance of small package drinking water treatment equipment by state drinking water regulatory officials and consulting engineers while reducing the need for testing of equipment at each location where the equipment use is contemplated. NSF will meet this goal by working with equipment Manufacturers and other agencies in planning and conducting equipment verification testing, evaluating data generated by such testing and managing and disseminating information. The Manufacturer is expected to secure the appropriate resources to support their part of the equipment verification process, including provision of equipment and technical support.

The verification process established by EPA and NSF is intended to serve as a template for conducting water treatment verification tests that will generate high quality data for verification of equipment performance. The verification process is a model process that can help in moving small package drinking water equipment into routine use more quickly. The verification of an equipment's performance involves five sequential steps:

1. Development of a verification/Field Operations Document;
2. Execution of verification testing;
3. Data reduction, analysis, and reporting;
4. Performance and cost (labor, chemicals, energy) verification;
5. Report preparation and information transfer.

This verification testing program is being conducted by NSF International with participation of manufacturers, under the sponsorship of the EPA Office of Research and Development, National Risk Management Research Laboratory, Water Supply and Water Resources Division (WSWRD) - Cincinnati, Ohio. NSF's role is to provide technical and administrative leadership and support in conducting the testing. It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations.

Partnerships:
The U.S. EPA and NSF International (NSF) are cooperatively organizing and developing the ETV's Package Drinking Water Treatment Systems Pilot Project to meet community and commercial needs. NSF and the Association of State Drinking Water Administrators have an understanding to assist each other in promoting and communicating the benefits and results of the project.

ORGANIZATION AND INTENDED USE OF PROTOCOL AND TEST PLANS

NSF encourages the user of this protocol to also read and understand the policies related to the verification and testing of package drinking water treatment systems and equipment.

The first Chapter of this document describes the Protocol required in all studies verifying the performance of equipment or systems removing volatile organic contaminants, the public health goal of the Protocol. The remaining chapters describe the additional requirements for equipment and systems using specific technologies to attain the goals and objectives of the Protocol: the removal of volatile organic contaminants.

Prior to the verification testing of a package drinking water treatment systems, plants and/or equipment, the equipment manufacturer and/or supplier must select an NSF-qualified, Field Testing Organization. This designated Field testing Organization must write a "Field Operations Document". The equipment manufacturer and/or supplier will need this protocol and the test plans herein and other NSF Protocols and Test Plans to develop the Field Operations Document depending on the treatment technologies used in the unit processes or treatment train of the equipment or system. More than one protocol and/or test plan may be necessary to address the equipment's capabilities in the treatment of drinking water.

Testing shall be conducted by an NSF-qualified, Field Testing Organization that is selected by the Manufacturer. Water quality analytical work to be completed as a part of an NSF Equipment Verification Testing Plan shall be contracted with a State certified, third-party accredited (e.g. NSF) or EPA accredited laboratory. For information on a listing of NSF-qualified field testing organizations, contact NSF International.

ACKNOWLEDGMENTS

The USEPA and NSF International would like to acknowledge those persons who participated in the preparation, review and approval of this Protocol. Without their hard work and dedication to the project, this document would not have been approved through the process which has been set forth for this ETV project.

Chapter 1: EPA/NSF ETV Protocol for Equipment Verification Testing for Volatile Organic Chemical Removal - Requirements for All Studies

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CHAPTER 1

EPA/NSF ETV
PROTOCOL FOR EQUIPMENT VERIFICATION TESTING
FOR VOLATILE ORGANIC CHEMICAL REMOVAL

REQUIREMENTS FOR ALL STUDIES

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1.0 INTRODUCTION

This document is the study protocol to be used for verification testing of equipment designed to achieve removal of volatile organic chemicals (VOCs). The equipment Field Testing Organization is requested to adhere to the requirements of this study protocol in developing a Field Operations Document (FOD).

The testing of new technologies and materials that are unfamiliar to the NSF/EPA will not be discouraged. It is recommended that resins or membranes or any other material or chemical in the package plant conform to ANSI/NSF Standard 60 and 61.

The final submission of the FOD shall:

- include the information requested in this protocol;
- conform to the format identified herein;
- and conform to the specific NSF International (NSF) Equipment Verification Testing Plan or Plans related to the statement or statements of capabilities that are to be verified.

The FOD may include more than one Testing Plan. For example, testing might be undertaken to verify performance of a package plant employing aeration for removal of VOCs and for carbon dioxide removal to adjust pH.

This protocol document is presented in two fonts. The non-italicized font provides the rationale for the requirements and background information that the Field Testing Organization may find useful in preparation of the FOD. *The italicized text indicates specific study protocol deliverables that are required of the Field Testing Organization or of the Manufacturer and that must be incorporated in the FOD.*

The following glossary terms are presented here for subsequent reference in this protocol:

- Distribution System - A system of conduits by which a primary water supply is conveyed to consumers typically by a network of pipelines.

- EPA - The United States Environmental Protection Agency, its staff or authorized representatives.

- Equipment - Testing equipment for use in the Verification Testing Program which may be defined as either a package plant or modular system.

- Field Operations Document (FOD) - A written document of procedures for on-site/in-line testing, sample collection, preservation, and shipment and other on-site activities described in the EPA/NSF Protocol(s) and Test Plan(s) that apply to a specific make and model of a package plant/modular system.

- Field Testing Organization (FTO) - An organization qualified to conduct studies and testing of package plants or modular systems in accordance with protocols and test plans. The role of the Field Testing Organization is to complete the application on behalf of the company; to ensure preparation of an acceptable FOD; to enter into contracts with NSF, as discussed herein, arrange for or conduct the skilled operation of a package plant during the intense period of testing during the study and the tasks required by the protocol.

- Manufacturer - A business that assembles and/or sells package plant equipment and/or modular systems. The role of the manufacturer is to provide the package plant and/or modular system and technical support for the verification testing and study. The manufacturer is also responsible for providing assistance to the Field Testing Organization during operation and monitoring of the package plant or modular system during the verification testing and study.

- Modular System - A packaged functional assembly of components for use in a drinking water treatment system or packaged plant, that provides a limited form of treatment of the feedwater(s) and which is discharged to another module of the package plant or in the final step of treatment to the distribution system.

- NSF - NSF International, its staff, or other authorized representatives.

- Package Plant - A complete water treatment system including all components from connection to the raw water(s) through discharge to the distribution system.

- Plant Operator - The person working for a small water system who is responsible for operating package water treatment equipment to produce treated drinking water. This person also may collect samples, record data and attend to the daily operations of equipment throughout the testing periods.

- Protocol - A written document that clearly states the objectives, goals and scope of the study as well as the test plan(s) for the conduct of the study. Protocol shall be used for reference during Manufacturer participation in verification testing program.

- Report - A written document that includes data, test results, findings, and any pertinent information collected in accordance with a protocol, analytical methods, procedures, etc., in the assessment of a product whether such information is preliminary, draft or final form.

- Testing Plan - A written document that describes the procedures for conducting a test or study for the application of water treatment technology. At a minimum, the test plan will include detailed instructions for sample and data collection, sample handling and sample preservation, precision, accuracy, and reproducibility goals, and quality assurance and quality control requirements.

- Testing Laboratory - An organization certified by a third-party independent organization, federal agency, or a pertinent state regulatory authority to perform the testing of drinking water samples. The role of the testing laboratory in the verification testing of package plants and/or modular systems is to analyze the water samples in accordance with the methods and meet the pertinent quality assurance and quality control requirements described in the protocol, test plan and field operations document.

- Verification - to establish the evidence on the range of performance of equipment and/or device such as a package plant or modular system under specific conditions following a predetermined study protocol(s) and test plan(s).

- Verification Statement - A written document that summarizes a final report reviewed and approved by NSF on behalf of the EPA or directly by the EPA.

- Water System - The water system that operates package water treatment equipment to provide treated water to its customers.

1.1 Objectives

The specific objectives of verification testing may be different for each package plant or modular system, depending upon the statement of capabilities of the specific equipment to be tested. The objectives developed by each Manufacturer shall be defined and described in detail in the FOD developed for each piece of equipment. The objectives of the equipment verification testing may include:

- Generation of field data appropriate for verifying the performance of the equipment;
- Generation of field data in support of meeting current or anticipated water quality regulations;
- Evaluation of new advances in equipment and equipment design.

An important aspect in the development of the verification testing is to describe the procedures that will be used to verify the statement of performance capabilities made for water treatment equipment. A verification testing plan document incorporates the QA/QC elements needed to provide data of appropriate quality sufficient to reach a defensible position regarding the equipment performance. Verification testing conducted at a single site may not represent every environmental situation which may be acceptable for the equipment tested, but it will provide data of sufficient quality to make a judgment about the application of the equipment under conditions similar to those encountered in the verification testing.

1.2 Scope

This protocol outlines the verification process for equipment designed to remove VOCs. The scope of this protocol includes Testing Plans for package plants employing air stripping, carbon adsorption, and for other technologies for removal of VOCs.

An overview of the verification process and the elements of the FOD to be developed by the Field Testing Organization are described in this protocol. Specifically, the FOD shall define the following elements of the verification testing:

- Roles and responsibilities of verification testing participants;

- Procedures governing verification testing activities such as equipment operation and process monitoring; sample collection, preservation, and analysis; and data collection and interpretation;
- Experimental design of the Field Operations Procedures;
- Quality assurance (QA) and quality control (QC) procedures for conducting the verification testing and for assessing the quality of the data generated from the verification testing; and,
- Health and safety measures relating to biohazard (if present), electrical, mechanical and other safety codes.

Content of Field Operations Document:

The structure of the FOD must conform to the outline below: The required components of the Document shall be described in greater detail in the sections below.

- *TITLE PAGE;*
- *FOREWORD;*
- *TABLE OF CONTENTS -The Table of Contents for the FOD shall include the headings provided in this document although they may be modified as appropriate for a particular type of equipment to be tested;*
- *EXECUTIVE SUMMARY -The Executive Summary describes the contents of the FOD (not to exceed two pages). A general description of the equipment and the statement of performance capabilities which shall be verified during testing shall be included, as well as the testing locations, a schedule, and a list of participants;*
- *ABBREVIATIONS AND ACRONYMS - A list of the abbreviations and acronyms used in the FOD shall be provided;*
- *EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES (described in the sections below);*
- *EQUIPMENT CAPABILITIES AND DESCRIPTION (described in the sections below);*
- *EXPERIMENTAL DESIGN (described in the sections below);*
- *FIELD OPERATIONS PROCEDURES (described in the section below)*;
- *QUALITY ASSURANCE TESTING PLAN (described in the section below);*
- *DATA MANAGEMENT AND ANALYSIS (described in the section below);*
- *SAFETY PLAN (described in the section below).*

2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

2.1 Verification Testing Organization and Participants

The required content of the FOD and the responsibilities of participants are listed at the end of each section. In the development of a FOD, Manufacturers and their designated Field Testing Organization shall provide a table which includes the name, affiliation, and mailing address of each participant, a point of contact, their role, and telephone, fax and E-mail address.

2.2 Organization

The organizational structure for the verification testing showing lines of communication shall be provided by the Field Testing Organization in its application on behalf of the Manufacturer.

2.3 Verification Testing Site Name and Location

This section discusses background information on the verification testing site(s), with emphasis on the quality of the feedwater. The FOD must provide the site names and locations. In most cases, the equipment may be demonstrated at more than one site. In all cases, the equipment should be tested under different feedwater quality and seasonal weather and climate conditions.

2.4 Site Characteristics

The Manufacturer FOD shall include an area location map showing access from major streets and highways and a site layout drawing with equipment footprints and dimensions. The drawing should indicate the location of the existing facilities, the source of the feed water, and where the treated water will be discharged and the waste streams disposed. Indicate if any facilities other than the package plant would be required such as additional trailers or temporary structures for sample collection and preparation, electrical power, concrete pads, drainage, easements, etc. The location of the VOC waste stream treatment, disposal and discharge facility or method of removal shall be clearly identified in the site plan.

2.5 Responsibilities

This section identifies the organizations involved in the testing and describes the primary responsibilities of each organization. Additional listing of the responsibilities of the Field Testing Organization and the Manufacturer are provided in the attached Draft Summary Sheets. The responsibilities of the Manufacturer may vary depending on the type of verification testing. Multiple Manufacturer testing at one time is also an option.

In brief, the Field Testing Organization shall be responsible for:

- Providing needed logistical support, establishing a communication network, and scheduling and coordinating the activities of all verification testing participants;

- Ensuring that locations selected as test sites have feedwater quality consistent with the objectives of the verification testing (Manufacturer may recommend a verification testing site(s));

- Managing, evaluating, interpreting, and reporting on data generated by the verification testing;

- Evaluating and reporting on the performance of the technologies.

The Manufacturer shall be responsible for provision of the equipment to be evaluated.

Content of Field Operations Document Regarding Equipment Verification Testing Responsibilities:

The Field Testing Organization, shall be responsible for including the following elements in the FOD:

- *Definition of the roles and responsibilities of appropriate verification testing participants*

- *A table which includes the name, affiliation, and mailing address of each participant, a point of contact, their role, and telephone, fax and E-mail address;*

- *Organization of operational and analytical support;*

- *List of the site name(s) and location(s);*

- *Description of the test site(s), the site characteristics and identification of where the equipment shall be located.*

Manufacturer Responsibilities:

- *Provision of complete, field-ready equipment for verification testing;*

- *Provision of logistical, and technical support, as required;*

- *Provision of technical assistance to the qualified testing organization during operation and monitoring of the equipment undergoing verification testing.*

3.0 EQUIPMENT CAPABILITIES AND DESCRIPTION

3.1 Equipment Capabilities

The Manufacturer and their designated Field Testing Organization must identify the water quality objectives to be achieved in the statement of performance capabilities of the equipment to be evaluated in the verification testing. The manufacturer's FOD must state the treated water quality objectives of the equipment to be tested. Statements should also be made regarding the applications of the equipment, what advantages it provides over existing equipment and the known limitations of the equipment. The statement of performance capabilities must be specific and be verifiable by a statistical analysis of the data. An example of a satisfactory statement of performance capabilities would be:

> "This package plant is capable of reducing the concentration of 1,1,2-trichloroethylene or other VOC with a value of Henry's Law Constant greater than 1,1,2-trichloroethylene in water by at least an order of magnitude from a feedwater concentration of 40 ug/L to less than 5 ug/L in the treated water."

A statement of performance capabilities such as: "This package plant will provide lower VOC levels than required by the Safe Drinking Water Act on a consistent and dependable basis," would not be acceptable.

The statement of performance capabilities shall indicate the range of water quality with which the equipment can be challenged while successfully treating the feedwater. Statements of performance capabilities that are too easily met may not be of interest to the potential user, while performance capabilities that are overstated may not be achievable. The statement of performance capabilities forms the basis of the entire equipment verification testing and must be chosen appropriately. Therefore, the design of the FOD shall include a sufficient range of feedwater quality to permit verification of the statement of performance capabilities.

3.2 Equipment Description

Description of the equipment for verification testing shall be included in the FOD. Data plates shall be permanent and securely attached to each production unit. The data plate shall be easy to read in English or the language of the intended user, located on the equipment where it is readily accessible, and contain at least the following information:

a. Equipment Name;
b. Model #;
c. Manufacturer's name and address;
d. Electrical requirements - volts, amps, and Hertz;
e. Serial Number;
f. Warning and Caution statements in legible and easily discernible print size;
g. Capacity or output rate (if applicable).

Content of Field Operations Document Regarding Equipment Capabilities and Description:

The FOD shall include the following documents:

- *Description of the equipment to be demonstrated including photographs from relevant angle or perspective;*

- *Brief introduction and discussion of the engineering and scientific concepts on which the water treatment equipment is based;*

- *Description of the treatment train and each unit process included in the package plant including all relevant schematics;*

- *Brief description of the physical construction/components of the equipment, including the general environmental requirements and limitations, weight, transportability, ruggedness, power and other consumables needed, etc.;*

- *Statement of typical rates of consumption of chemicals, a description of the physical and chemical nature of wastes, and rates of waste production; concentrates, residues, etc.;*

- *Definition of the performance range of the equipment;*

- *Identification of any special licensing requirements associated with the operation of the equipment;*

- *Description of the applications of the equipment and the removal capabilities of the treatment system relative to existing equipment by providing comparisons in such areas as: treatment capabilities, requirements for chemicals and materials, power, labor requirements, suitability for process monitoring and operation from remote locations, ability to be managed by part-time operators;*
- *Discussion of the known limitations of the equipment by including such items as the range of feedwater quality suitable for treatment with the equipment, the upper limits for concentrations of regulated contaminants that can be removed to concentrations below the maximum contaminant level (MCL), level of operator skill required to successfully use the equipment.*

4.0 EXPERIMENTAL DESIGN

This section discusses the objectives of the verification testing, factors that must be considered to meet the performance objectives, and the statistical and other means that the Field Testing Organization should use to evaluate the results of the verification testing.

4.1 Objectives

The objectives of this verification testing are to evaluate equipment in the following areas: (1) performance relative to manufacturer's stated range of equipment capabilities; 2) how well it performs relative to the requirements of the Safe Drinking Water Act (SDWA) and its relevant amendments and any other specific or immediately anticipated water quality regulation; 3) the impacts of variations in feedwater quality (such as VOC concentrations and temperature) on its performance; 5) the logistical, human, and economic resources necessary to operate the equipment; 6) the reliability, ruggedness, cost, range of usefulness, and ease of operation; and 7) identify secondary impacts of treatment relative to SDWA regulations such as corrosivity under the Lead and Copper Rule.

A FOD shall include those treatment tests listed in NSF test plans that are most appropriate to challenge the equipment. For example, if equipment is only intended for removal of vinyl chloride, there would be no need to conduct testing to evaluate the removal of benzene or toluene.

4.2 Equipment Characteristics

This section discusses factors that shall be considered in the design and implementation of the verification testing. These factors include ease of operation, degree of operator attention required, response of equipment and treatment process to changes in feedwater quality, electrical requirements, system reliability features including redundancy of components, feed flow requirements, discharge requirements, spatial requirements for the equipment (footprint), unit processes included in treatment train, and chemicals needed.

Verification testing procedures shall simulate routine conditions as much as possible and in most cases testing may be done in the field; hence in that circumstance simulation of field conditions would not be necessary.

4.2.1 Qualitative Factors

Some factors, while important, are difficult or impractical to quantify. These are considered qualitative factors. Important factors that cannot easily be quantified are the safety of the equipment and the logistical requirements necessary for using it.

Typical qualitative factors to be discussed are listed below, and others may be added. The FOD shall discuss those factors that are appropriate to the test equipment.

- Reliability or susceptibility to environmental conditions;
- Equipment safety;
- Potential for nuisance noise;
- Need for alarms, security and/or lighting;
- Effect of operator experience on results.

4.2.2 Quantitative Factors

Many factors in this verification testing can be quantified by various means. Some can be measured while others cannot be controlled. Typical quantitative factors to be discussed are listed below, and others may be added. The FOD shall discuss those factors that are appropriate to the test equipment.

- Power and consumable supply (such as chemical) requirements;
- Monitoring requirements;
- Cost of operation, expendables, and waste disposal;
- Length of operating cycle;
- Modular size and weight of the equipment.

These quantitative factors shall be used as an initial benchmark to assess equipment performance.

4.3 Water Quality Considerations

Water treatment equipment is used to treat water and change the quality of feedwater (or raw water) so it meets the requirements of the Safe Drinking Water Act, amendments to the Safe Drinking Water Act, and any other appropriate regulation. In the near future this will include the Groundwater Disinfection Rule, Enhanced Surface Water Treatment Rule, and Disinfectant/Disinfection By Products Rule. The experimental design shall be developed so the relevant questions about water treatment equipment capabilities can be answered.

Equipment Manufacturers should recognize that it is highly unlikely that any single item of water treatment process equipment can successfully treat any conceivable feedwater containing all of the regulated contaminants and produce a treated water that meets the quality requirements for every regulated contaminant. Although multiple processes could be placed in a treatment train to accomplish such a goal, for most public water systems such comprehensive treatment capability is not needed and would not be cost effective. Therefore, drinking water treatment has been focused on the water quality aspects of concern for particular locations.

The range of contaminants or water quality problems that can be addressed by water treatment equipment varies, and some package treatment equipment can address a broader range of problems than other types. Manufacturers should carefully consider the capabilities and limitations of their equipment and have FODs prepared that challenge their equipment sufficiently to enable the verification testing to provide a broad market for their products, while recognizing the limitations of the equipment and not subjecting it to testing for contaminant removal when the outcome is known in advance to be failure and the testing would be fruitless. Field Testing Organizations shall use NSF Equipment Verification Testing Plans as the basis for preparation of the specific FODs.

4.3.1 Feedwater Quality

One of the key aspects related to water treatment equipment performance verification is the range of feedwater quality that can be treated successfully, resulting in treated water quality that meets water quality goals or regulatory requirements. The Manufacturer and Field Testing Organization should consider the influence of feedwater quality on the quality of treated waters produced by the package plant, such that product waters meet the water quality goals or regulatory requirements. As the range of feedwater quality that can be treated by the equipment becomes broader, the potential applications for treatment equipment with verified performance capabilities may also increase.

One of the questions often asked by regulatory officials in approval of package water treatment equipment is "Has it been shown to work on the water where you propose to put it?" By covering a large range of water qualities the verification testing is more likely to provide an affirmative answer to that question.

The Field Testing Organization shall specify in the FOD the specific water quality parameters to be monitored in the Verification Testing Program. The following feedwater quality characteristics may be important for treatment equipment intended to remove volatile organic chemicals:

- volatile organic compound concentration;
- temperature.

The following feedwater quality characteristics may be important to potential fouling and/or scaling of treatment equipment over time and should be noted if present in a quantity that could affect longer term operation:

- total hardness and/or calcium hardness;
- pH and alkalinity;
- corrosivity (Langelier index);
- iron and manganese;

- total dissolved solids or conductivity;
- total sulfide;
- sulfate;
- dissolved oxygen;
- presence of bacteria;
- presence of algae;
- dissolved organic carbon (DOC), total organic carbon (TOC), or UV-254 absorbance;
- turbidity, particle concentration.

4.3.2 Treated Water Quality

Treated water quality is very important. If a Field Testing Organization states that water treatment equipment can be used to treat water to meet specified regulatory requirements, the verification testing must provide data that support such a statement of capabilities.

In addition, the Field Testing Organization may wish to make a statement about performance capabilities of the equipment for removal of other regulated contaminants under the SDWA.

Furthermore, some water treatment equipment can be used to meet aesthetic goals that are not included as regulatory requirements of the Safe Drinking Water Act. Water quality considerations that go beyond regulatory requirements and may be important for some small systems include:

- taste and odor;
- total dissolved solids;
- iron and manganese.

4.4 Recording Data

For all volatile organic chemical removal experiments, data should be maintained on the pH, temperature and other water quality parameters listed in Sections 4.3.1 and 4.3.2 above. The following items of information shall also be maintained for each experiment:

- Type of chemical addition, dose and chemical combination, where applicable (e.g., pH adjustment, scale inhibitor, etc.);
- Water type (raw water, pretreated feedwater, product water, waste water);
- Experimental run (e.g. 1st run, 2nd run, 3rd run, etc.).

4.5 Recording Statistical Uncertainty

For the analytical data obtained during verification testing, 95% confidence intervals shall be calculated by the Field Testing Organization for selected water quality parameters. The specific testing plans shall specify which water quality parameters shall be subjected to the requirements of confidence interval calculation. As the name implies, a confidence interval describes a population range in which any individual population measurement may exist with a specified percent confidence.

The following formula shall be employed for confidence interval calculation:

$$confidence\ \ interval\ = \overline{X} \pm t_{n-1,1-\frac{\alpha}{2}}(S/\sqrt{n})$$

where: X is the sample mean;
S is the sample standard deviation;
n is the number of independent measurements included in the data set; and
t is the Student's t distribution value with n-1 degrees of freedom;
α is the significance level, defined for 95% confidence as: 1 - 0.95 = 0.05.

According to the 95% confidence interval approach, the α term is defined to have the value of 0.05, thus simplifying the equation for the 95% confidence interval in the following manner:

$$95\%\ \ confidence\ \ interval\ = \overline{X}\ \pm t_{n-1,0.975}\ (S/\sqrt{n})$$

With input of the analytical results for pertinent water quality parameters into the 95% confidence interval equation, the output will appear as the sample mean value plus or minus the second term. The results of this statistical calculation may also be presented as a range of values falling within the 95% confidence interval. For example, the results of the confidence interval calculation may provide the following information: 520 +/- 38.4 µg/L, with a 95% confidence interval range described as (482, 558).

Calculation of confidence intervals shall not be required for equipment performance results (e.g., time between cleanings, cleaning efficiency, etc.) obtained during the equipment testing verification program. However, as specified by the Field Testing Organization, calculation of confidence intervals may be required for such analytical parameters as grab sample alkalinity, iron concentration, and DOC. In order to provide sufficient analytical data for statistical analysis, the Field Testing Organization shall collect three discrete water samples at one set of operational conditions for each of the specified water quality parameters during a designated testing period. The procedures and sampling requirements shall be provided in detail in the Verification Testing Plan.

4.6 Verification Testing Schedule

Verification testing activities include equipment set-up, initial operation, verification operation, and sampling and analysis. Initial operations are intended to be conducted so equipment can be tested to be sure it is functioning as intended. If feedwater quality influences operation and performance of equipment being tested, the initial operations period serves as the shake-down period for determining appropriate operating parameters. The schedule of testing may also be influenced by coordination requirements with a utility.

One period of verification testing shall be designated, including the coldest temperatures expected because of the impact of cold temperatures on physical properties of the VOCs and an increase in the viscosity of water.

Verification testing with operations for which data are collected and used to verify performance would be done after initial operations are completed.

Content of Field Operations Document Regarding Experimental Design:

The FOD shall include the following elements:

- *Identification of the qualitative and quantitative factors of equipment operation to be addressed in the verification testing program;*

- *Identification and discussion of the water treatment problem or problems that the equipment is designed to address, how the equipment will solve the problem, and who would be the potential users of the equipment;*

- *Identification of the range of key water quality parameters, given in applicable NSF Testing Plans, which the equipment is intended to address and for which the equipment is applicable;*

- *Identification of the key parameters of treated water quality that shall be used for evaluation of equipment performance during the physical removal of microbiological and particulate contaminants. Parameters of significance for treated water quality were listed above in Section 4.3.2. and in applicable NSF Testing Plans;*

- *Description of the confidence interval calculation procedure for selected water quality parameters;*

- *Detailed outline of the verification testing schedule, with regard to annual testing periods that will cover an appropriate range of annual climatic conditions, (i.e., different temperature conditions, seasonal differences between rainy and dry conditions).*

5.0 FIELD OPERATIONS PROCEDURES

5.1 Equipment Operations and Design

The NSF Verification Testing Plan specifies procedures that shall be used to ensure the accurate documentation of both water quality and equipment performance. Careful adherence to these procedures will result in definition of verifiable performance of equipment. (Note that this protocol may be associated with a number of different NSF Equipment Verification Testing Plans for different types of VOC removal process equipment.)

Design aspects of water treatment process equipment often provide a basis for approval by state regulatory officials and can be used to ascertain if process equipment intended for larger or smaller flows involves the same operating parameters that were relevant to the verification testing. Specific design aspects to be included in the FOD are provided in detail, in the Manufacturer Responsibilities section below.

5.2 Communications, Documentation, Logistics, and Equipment

The successful implementation of the verification testing will require detailed coordination and constant communication between all verification testing participants. All field activities shall be thoroughly documented. Field documentation shall include field logbooks, photographs, field data sheets, and chain-of-custody forms. The qualified Field Testing Organization shall be responsible for maintaining all field documentation. Field notes shall be kept in a bound logbook. Each page shall be sequentially numbered and labeled with the project name and number. Field logbooks shall be used to record all water treatment equipment operating data. Completed pages shall be signed and dated by the individual responsible for the entries. Errors shall have one line drawn through them and this line shall be initialed and dated.

All photographs shall be logged in the field logbook. These entries shall include the time, date, direction, subject of the photograph, and the identity of the photographer. Any deviations from the approved final FOD shall be thoroughly documented in the field logbook at the time of inspection and in the verification report.

Original field sheets and chain-of-custody forms shall accompany all samples shipped to the analytical laboratory. Copies of field sheets and chain-of-custody forms for all samples shall be provided at the time of the QA/QC inspection and included in the verification report.

5.3 Initial Operations

Initial operations will allow equipment Manufacturers to refine their operating procedures and to make operation adjustments as needed to successfully start-up and shakedown the equipment. Information generated through this period of operation may be used to revise the FOD, if necessary. A failure at this point in the verification testing could indicate a lack of capability of the process equipment and the verification testing might be canceled.

5.4 Equipment Operation and Water Quality Sampling for Verification Testing

All field activities shall conform with requirements provided in the FOD that was developed and approved for the verification testing being conducted. If unanticipated or unusual situations are encountered that may alter the plans for equipment operation, water quality sampling, or data quality, the situation must be discussed with the NSF technical lead. Any deviations from the approved final FOD shall be thoroughly documented.

During routine operation of water treatment equipment, the total number of hours during which the equipment was operated each day shall be documented. In addition, the number of hours each day during which the operator was working at the treatment plant and performing tasks related to water treatment and the operation of the treatment equipment shall be documented, and the tasks performed during equipment operation shall be described by the Field Testing Organization, the Water System or the Plant Operator.

Content of Field Operations Document Regarding Field Operations Procedures:

The FOD shall include the following elements:

- *A table summary of the proposed time schedule for operating and testing;*
- *Field operating procedures for the equipment and performance testing, based upon the NSF Equipment Verification Testing Plan with listing of operating parameters, ranges for feedwater quality, and the sampling and analysis strategy.*

Manufacturer Responsibilities:

- *Provision of all equipment needed for field work associated with this verification testing;*
- *Provision of a complete list of all equipment to be used in the verification testing. A table format is suggested;*
- *Provision of field operating procedures.*

6.0 QUALITY ASSURANCE PROJECT PLAN (QAPP)

The QAPP for this verification testing specifies procedures that shall be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the verification testing will provide sound analytical results that can serve as the basis for performance verification.

6.1 Purpose and Scope

The purpose of this section is to outline steps that shall be taken by operators of the equipment and by the analytical laboratory to ensure that data resulting from this verification testing is of known quality and that a sufficient number of critical measurements are taken.

6.2 Quality Assurance Responsibilities

A number of individuals may be responsible for monitoring equipment operating parameters and for sampling and analysis QA/QC throughout the verification testing. Primary responsibility for ensuring that both equipment operation and sampling and analysis activities comply with the QA/QC requirements of the FOD (Section 6) shall rest with the Field Testing Organization.

QA/QC activities for the analytical laboratory that analyzes samples sent off-site shall be the responsibility of that analytical laboratory's supervisor. If problems arise or any data appear unusual, they shall be thoroughly documented and corrective actions shall be implemented as specified in this section. The QA/QC measurements made by the off-site analytical laboratory are dependent on the analytical methods being used.

6.3 Data Quality Indicators

The data obtained during the verification testing must be of sound quality for conclusions to be drawn on the equipment. For all measurement and monitoring activities conducted for equipment verification, the NSF and EPA require that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include four indicators of data quality: accuracy, precision, representativeness, and statistical uncertainty.

Treatment results generated by the equipment must be verifiable for the purposes of this program to be fulfilled. High quality, well documented analytical laboratory results are essential for meeting the purpose and objectives of this verification testing. Therefore, the following indicators of data quality shall be closely evaluated to determine the performance of the equipment when measured against data generated by the analytical laboratory.

6.3.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data. In this verification testing, representativeness will be ensured by executing consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, and sample shipping. Representativeness also will be ensured by using each method at its optimum capability to provide results that represent the most accurate and precise measurement it is capable of achieving.

For equipment operating data, representativeness entails collecting a sufficient quantity of data during operation to be able to detect a change in operations. For most water treatment processes involving microbiological and particulate contaminant removal, detecting a +/- 10 percent change in an operating parameter (e.g. headloss) is sufficient. Mixing energies and flows shall be recorded on a daily basis in order to track changes in operational conditions that exceed this 10 percent range.

6.3.2 Statistical Uncertainty

Statistical uncertainty of the water quality parameters analyzed shall be evaluated through calculation of the 95% confidence interval around the sample mean. Description of the confidence interval calculation is provided in Section 4.5 - Recording Statistical Uncertainty.

6.3.3 Accuracy

For water quality analyses, accuracy refers to the difference between a sample result and the reference or true value for the sample. Loss of accuracy can be caused by such processes as errors in standards preparation, equipment calibrations, loss of target analyte in the extraction process, interferences, and systematic or carryover contamination from one sample to the next.

In this verification testing, the FTO will be responsible for maintaining consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, and sample shipping to maintain a high level of accuracy in system monitoring. The FTO shall discuss the applicable ways of determining the accuracy of the chemical and microbiological samples and analytical techniques in the FOD.

For equipment operating parameters, accuracy refers to the difference between the reported operating condition and the actual operating condition. For water flow, accuracy is the difference between the reported flow indicated by a flow meter and the flow as actually measured on the basis of known volumes of water and carefully defined times (bucket and stopwatch technique) as practiced in hydraulics laboratories or water meter calibration shops. For mixing equipment, accuracy is the difference between an electronic readout for equipment RPMs and the actual measurement based on counted revolutions and measured time. Accuracy of head loss measurement can be determined by using measuring tapes to check the calibration of piezometers for gravity filters or by checking the calibration of pressure gauges for pressure filters. Meters and gauges must be checked periodically for accuracy, and when proven to be dependable over time, the time interval between accuracy checks can be increased. In the FOD, the FTO shall discuss the applicable ways of determining the accuracy of the operational conditions and procedures.

From an analytical perspective, accuracy represents the deviation of the analytical value from the known value. Since true values are never known in the field, accuracy measurements are made on analysis of QC samples analyzed with field samples. QC samples for analysis shall be prepared with laboratory control samples, matrix spikes and spike duplicates. It is recommended for verification testing that the FOD include laboratory performance of one matrix spike for determination of sample recoveries. Recoveries for spiked samples are calculated in the following manner:

% Recovery = 100 x (SSR-SR)/SA

where: SSR = spiked sample results
SR = sample result
SA = spike amount added

Recoveries for laboratory control samples are calculated as follows:

% Recovery = 100 x (found concentration)/(true concentration)

For acceptable analytical accuracy under the verification testing program, the recoveries reported during analysis of the verification testing samples must be within control limits, where control limits are defined as the mean recovery plus or minus three times the standard deviation.

6.3.4 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. Analytical precision is a measure of how far an individual measurement may be from the mean of replicate measurements. The standard deviation and the relative standard deviation recorded from sample analyses may be reported as a means to quantify sample precision. The percent relative standard deviation may be calculated in the following manner:

$$\%\text{Relative Standard Deviation} = S(100) / X_{average}$$

where: S = standard deviation
$X_{average}$ = the arithmetic mean of the recovery values.

Standard Deviation is calculated as follows:

$$\text{Standard Deviation} = \sqrt{\frac{(X_i - X)^2}{n-1}}$$

Where: X_i = the individual recovery values
X = the arithmetic mean of then recovery values
n = the number of determinations.

For acceptable analytical precision under the verification testing program, the percent relative standard deviation for drinking water samples must be less than 30%.

6.4 Quality Control Checks

This section describes the QC requirements that apply to both the treatment equipment and the on-site water quality analyses. It also contains a discussion of the corrective action to be taken if the QC parameters fall outside of the evaluation criteria.

The quality control checks provide a means of measuring the quality of data produced. The Field Testing Organization may not need to use all the ones identified in this section. The selection of the appropriate quality control checks depends on the equipment, the experimental design and the performance goals. The selection of quality control checks shall be based on discussions among the Manufacturer, the Field Testing Organization and NSF.

6.4.1 Quality Control for Equipment Operation

This section will explain the methods to be used to check on the accuracy of equipment operating parameters and the frequency with which these quality control checks shall be made. If the quality of the equipment operating data can not be verified, then the water quality analytical results may be of no value. Because water can not be treated if equipment is not operating, obtaining valid equipment operating data is a prime concern for verification testing.

An example of the need for QC for equipment operations is an incident of state rejection of test data because the treatment equipment had no flow meter to use for determining engineering and operating parameters related to flow.

6.4.2 Water Quality Data

After treatment equipment is being operated and water is being treated, the results of the treatment are interpreted in terms of water quality. Therefore the quality of water sample analytical results is just as important as the quality of the equipment operating data. Most QA plans emphasize analytical QA. The important aspects of sampling and analytical QA are given below:

6.4.2.1 Duplicate Samples: Duplicate samples must be analyzed to determine the precision of analysis. The procedure for determining samples to be analyzed in duplicate shall be provided with the frequency of analysis and the approximate number.

6.4.2.2 Method Blanks: Method blanks are used to evaluate analytical method-induced contamination, which may cause false positive results.

6.4.2.3 Spiked Samples: The use of spiked samples will depend on the testing program, and the contaminants to be removed. If spiked samples are to be used specify the procedure, frequency, acceptance criteria, and actions if criteria are not met.

6.4.2.4 Travel Blanks: Travel blanks shall be provided to the analytical laboratory to evaluate travel-related contamination.

6.4.2.5 Performance Evaluation Samples for On-Site Water Quality Testing: Performance evaluation (PE) samples are samples whose composition is unknown to the analyst that are used to evaluate analytical performance. Analysis of PE samples shall be conducted before pilot testing is initiated. PE samples shall be submitted by the Field Testing Organization to the analytical laboratory. The control limits for the PE samples shall be used to evaluate the equipment testing organization's and analytical laboratory's method performance. One kind of PE sample that would be used for on-site QA in most studies done under this protocol would be a volatile organic compound PE sample.

PE samples come with statistics about each sample which have been derived from the analysis of the sample by a number of laboratories using EPA-approved methods. These statistics include a true value of the PE sample, a mean of the laboratory results obtained from the analysis of the PE sample, and an acceptance range for sample values. The analytical laboratory is expected to provide results from the analysis of the PE samples that meet the performance objectives of the verification testing.

6.5 Data Reduction, Validation, and Reporting

To maintain good data quality, specific procedures shall be followed during data reduction, validation, and reporting. These procedures are detailed below.

6.5.1 Data Reduction

Data reduction refers to the process of converting the raw results from the equipment into concentration or other data in a form to be used in the comparison. The procedures to be used will be equipment dependent. The purpose of this step is to provide data which shall be used to verify the statement of performance capabilities. These data shall be obtained from logbooks, instrument outputs, and computer outputs as appropriate.

6.5.2 Data Validation

The operator shall verify the completeness of the appropriate data forms and the completeness and correctness of data acquisition and reduction. The field team supervisor or another technical person shall review calculations and inspect laboratory logbooks and data sheets to verify accuracy, completeness. Calibration and QC data shall be examined by the individual operators and the laboratory supervisor. Laboratory and project managers shall verify that all instrument systems are in control and that QA objectives for accuracy, completeness, and method detection limits have been met.

Analytical outlier data are defined as those QC data lying outside a specific QC objective window for precision and accuracy for a given analytical method. Should QC data be outside of control limits, the analytical laboratory or field team supervisor shall investigate the cause of the problem. If the problem involves an analytical problem, the sample shall be reanalyzed. If the problem can be attributed to the sample matrix, the result shall be flagged with a data qualifier. This data qualifier shall be included and explained in the final analytical report.

6.5.3 Data Reporting

This section contains a list of the water quality and equipment operation data to be reported. At a minimum, the data tabulation shall list the results for feedwater and treated water quality analyses and equipment operating data. All QC information such as calibrations, blanks and reference samples are to be included in an appendix. All raw analytical data shall also be reported in an appendix. All data shall be reported in hard copy and electronically in a common spreadsheet or database format.

6.6 Calculation of Data Quality Indicators

The equations for any data quality indicator calculations employed shall be provided. These include: precision, relative percent deviation, standard deviation, accuracy, and completeness.

6.7 System Inspections

On-site system inspections for sampling activities, field operations, and laboratories may be conducted as specified by the NSF Equipment Verification Testing Plan. These inspections will be performed by the verification entity to determine if the NSF Equipment Verification Testing Plan is being implemented as intended. Separate inspection reports will be completed after the inspections and provided to the participating parties.

6.8 Reports

6.8.1 Status Reports

The Field Testing Organization shall prepare periodic reports for distribution to pertinent parties, e.g., manufacturer, EPA, the community. These reports shall discuss project progress, problems and associated corrective actions, and future scheduled activities associated with the verification testing. When problems occur, the Manufacturer and Field Testing Organization project managers shall discuss them and estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems. The frequency, format, and content of these reports shall be outlined in the FOD.

6.8.2 Inspection Reports

Any QA inspections that take place in the field or at the analytical laboratory while the verification testing is being conducted shall be formally reported by the Field Testing Organization to the verification entity and manufacturer.

6.9 Corrective Action

Each FOD must incorporate a corrective action plan. This plan must include the predetermined acceptance limits, the corrective action to be initiated whenever such acceptance criteria are not met, and the names of the individuals responsible for implementation.

Routine corrective action may result from common monitoring activities, such as:

- Performance evaluation audits; and,
- Technical systems audits.

Content of Field Operations Document Regarding Quality Assurance Project Plan:

The FOD shall include the following elements:

- *Description of methodology for measurement of accuracy;*
- *Description of methodology for measurement of precision;*
- *Description of the methodology for use of blanks, the materials used, the frequency, the criteria for acceptable method blanks and the actions if criteria are not met;*
- *Description of any specific procedures appropriate to the analysis of the samples;*
- *Outline of the procedure for determining samples to be analyzed in duplicate, the frequency and approximate number;*
- *Description of the procedures used to assure that the data are correct;*
- *Listing of equations used for any necessary data quality indicator calculations. These include: precision, relative percent deviation, standard deviation, accuracy, and completeness;*
- *Outline of the frequency, format, and content of reports in the FOD; and,*
- *Development of a corrective action plan in the FOD.*

Field Testing Organization Responsibilities:

- *Provision of all QC information such as calibrations, blanks and reference samples in an appendix. All raw analytical data shall also be reported in an appendix.*
- *Provision of all data in hard copy and electronic form in a common spreadsheet or database format.*

7.0 DATA MANAGEMENT AND ANALYSIS, AND REPORTING

7.1 Data Management and Analysis

The responsibilities of the Field Testing Organization for data management and analysis have been provided in the Responsibilities Summary Sheet, the Project Guidance Manual, and/or the Terms and Conditions cited earlier in this protocol.

A variety of data may be generated during a verification testing. Each piece of data or information identified for collection in the NSF Equipment Verification Testing Plan shall be provided in the report. The data management section of the FOD shall describe what types of data and information needs to be collected and managed. It shall also describe how the data shall be reported to the NSF for evaluation.

Laboratory Analyses: The raw data and the validated data must be reported. These data shall be provided in hard copy and in electronic format. As with the data generated by the equipment, the electronic copy of the laboratory data shall be provided in a spreadsheet in the report. In addition to the sample results, all QA/QC summary forms must be provided.

Other items that must be provided include:

- field notebooks;
- photographs, slides and videotapes (copies); and,
- results from the use of other field analytical methods.

7.2 Report of Equipment Testing

The Field Testing Organization shall prepare a draft report describing the verification testing that was carried out and the results of that testing. This report shall include the following topics:

- Introduction;
- Executive Summary;
- Description and Identification of Product Tested;
- Procedures and Methods Used in Testing;
- Results and Discussion;
- References;
- Appendices;
- FOD;
- QA/QC Results;
- Items described in section 7.1 of this document.

Content of Manufacturer Field Operations Document Regarding Data Management and Analysis, and Reporting:

The FOD shall include the following:

- *Description of what types of data and information needs to be collected and managed.*
- *Description of how the data will be reported.*

8.0 SAFETY MEASURES

The safety procedures shall address safety considerations, including the following as applicable:

- storage, handling, and disposal of hazardous chemicals including VOCs, acids, caustic and oxidizing agents;
- conformance with National Electric Code;
- conformance with building permits;
- presence on site and familiarity with applicable Material Safety Data Sheets;
- biohazards, if pathogenic microorganisms are used in testing;
- ventilation of equipment or of trailers or buildings housing equipment, if gases generated by the equipment could present a safety hazard (one example is ozone);
- needs for fire extinguishers, site security, site lighting, and/or air conditioning.

Content of Field Operations Document Regarding Safety:

The FOD shall address safety considerations that are appropriate for the equipment being tested and for the challenge organisms, if any, being used in the verification testing.

CHAPTER 2

EPA/NSF ETV
EQUIPMENT VERIFICATION TESTING PLAN FOR REMOVAL OF VOLATILE ORGANIC CHEMICALS BY AIR STRIPPING TECHNOLOGY

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1.0 APPLICATION OF THIS NSF EQUIPMENT VERIFICATION TESTING PLAN

This document is the NSF Equipment Verification Testing Plan for Volatile Organic Compound (VOC) Removal by Air Stripping Technology Used in Packaged and/or Modular Drinking Water Treatment Systems for Small Public or Private Water Supplies. This Testing Plan is to be used as a guide in the development of the Field Operations Document for testing of air stripping equipment, within the structure provided by the NSF Protocol document for VOC removal. Refer to the "Protocol For Equipment Verification Testing For VOC Removal" for further information.

In order to participate in the equipment verification process for air stripping, the equipment Manufacturer and their designated Field Testing Organization shall employ the procedures and methods described in this test plan and in the referenced NSF Protocol Document as guidelines for the development of the Field Operations Document. The Field Operations Document should generally follow those Tasks outlined herein, with changes and modifications made for adaptations to specific air stripping equipment. As appropriate, the format of the procedures written for each Task should consist of the following sections:

- Introduction
- Objectives
- Work Plan
- Analytical Schedule
- Evaluation Criteria

Each Field Operations Document shall include Tasks 1 to 6 as identified below, with Task 7 being recommended but optional.

2.0 INTRODUCTION

Air stripping involves the transfer of volatile aqueous contaminants from water to air. Air stripping, sometimes referred to as aeration, involves continuous contact of air with water to allow aqueous contaminants to transfer. The air is swept from the system, treated as necessary, and released to the atmosphere. The driving force for transfer of the contaminants is the difference between the concentration of the contaminant in untreated water and the concentration in water that is at equilibrium with the air.

This plan is applicable to any type of air stripping process as long as it is adequately described by the Manufacturer. Various air stripping processes are currently employed for water treatment applications including:

- packed tower, employing either structured or loose packing;
- shallow tray;
- diffused air;
- spray; and
- gas permeable hollow fiber membrane.

3.0 GENERAL APPROACH

This NSF Equipment Verification Testing Plan is broken down into 7 tasks. As noted above, Tasks 1 to 6 shall be performed by any Manufacturer wanting the performance of their equipment verified by NSF. Task 7 is a recommended but optional task. The Manufacturer's designated Field Testing Organization shall provide full detail of the procedures to be followed in each Task in the Field Operations Document. The Field Testing Organization shall specify the operational conditions to be verified during the Verification Testing Plan.

The verification testing plan shall be performed in a series of short-term testing events for each operating condition to be verified. For surface water applications proper pretreatment must be applied as specified by the manufacturer. Testing shall be performed in the coldest period of the year. In addition, for each feed water tested a 30-day long-term testing period of continuous operation may be performed in the warmest period of the year to determine the effect of scaling and biofouling on the performance of the equipment.

Air stripping results in the transfer of VOCs from the feed water to air. Treatment of the air phase to meet applicable regulations may be necessary. Treatment of the air exiting the air stripping equipment is not considered part of this equipment verification, and thus a verification of equipment performance under this test plan does not constitute verification of any air treatment system.

4.0 OVERVIEW OF TASKS

The following section provides a brief overview of the required tasks to be included in the air stripping verification testing program.

4.1 Task 1: Characterization of Feed Water

The objective of this task is to obtain a chemical, biological and physical characterization of the feed water. A brief description of the origin of the feed water shall be provided to aid in interpretation of these characteristics.

4.2 Task 2: Verification Testing

Water treatment equipment shall be operated under steady state conditions for at least eight hours per operational condition to be verified, during the coldest period of the year, to collect data on equipment performance and water quality for purposes of performance verification.

4.3 Task 3: Operating Conditions and System Performance

During each operational condition of Verification Testing, operating conditions and performance of the water treatment equipment shall be documented. Operating conditions include water loading rate, air loading rate, and water temperature. Equipment performance involves measurement of the air pressure drop and determination of potential precipitative scaling or biological fouling.

4.4 Task 4: Finished Water Quality

The objective of this task is to evaluate the quality of water produced by the air stripping process. Multiple water quality parameters will be monitored during the testing period. The mandatory water quality monitoring parameters shall include: temperature, calcium hardness, alkalinity, pH, dissolved oxygen and the VOCs to be treated. A basic goal of this Task is to confirm that treated waters meet Maximum Contaminant Limits (MCLs) for each VOC of interest, or to confirm percentage removal of a variety of VOCs with a range of Henry's Law coefficients (H). The latter goal will allow for extrapolation of performance verification under identical operating conditions to other VOCs based on H. Water quality produced will be evaluated in relation to feed water quality and operational conditions.

4.5 Task 5: Data Management

The objective of this task is to establish effective field protocol for data management at the field operations site and for data transmission between the Field Testing Organization and the NSF.

4.6 Task 6: QA/QC

An important aspect of verification testing is the protocol developed for quality assurance and quality control. The objective of this task is to assure accurate measurement of operational and water quality parameters during air stripping equipment verification testing.

4.7 Task 7: Effect of Scaling or Biofouling (Recommended)

This task is performed in order to determine the reduction in VOC removal efficiency as a result of precipitative scaling or biofouling of the air stripping media. This task should be performed over a 30-day period of continuous operation in the warmest period of the year.

5.0 TESTING PERIOD

The required tasks of the NSF Equipment Verification Testing Plan (Tasks 1 through 6) are designed to be completed in one testing period, not including mobilization, shakedown and start-up. VOC removal verification shall be performed in the coldest period of the year. The effect of scaling and biofouling (recommended Task 7) should be performed in a 30-day period during the warmest period of the year.

Cold weather operations will be an important component of water quality testing for surface water sources because of the impact of cold temperatures (1^{o} C to 5^{o} C) on water viscosity, diffusional processes and contaminant volatility. In particular, for air stripping equipment, factors that can influence treatment performance include:

- Cold water, encountered in winter or at high altitude locations in mountainous regions of the country.

- Feed waters with high hardness, or iron which may promote precipitation of inorganic materials in the equipment, accelerating the need for chemical cleaning.

Warm weather long-term operation may also be an important component of performance testing because of the impact of warm temperatures on aqueous solubility and bioactivity. In particular, for air stripping equipment, factors that can influence long-term treatment performance include:

- Warm temperatures, encountered in summer, which increase the rate of bioactivity, resulting in increased biofouling. In general, the rate of bioactivity doubles with a 10^{o}C increase in temperature.
- Warm temperatures also affect on the solubility of scalants. In most cases solubility decreases and scaling increases with an increase in water temperature.
- Feed waters with high total sulfur which may promote biofouling.

Each of the above may accelerate the need for chemical cleaning.

6.0 DEFINITIONS

6.1 Feed water: Water introduced to the air stripper.

6.2 Finished water: Water exiting the air stripper.

6.3 Packed Tower Aerator: A tower containing packing material which provides a large surface area for contact between water and air**.** Water is passed downflow through the tower and is broken into thin sheets and droplets while air flows up through the packing material. The packing material could be structured media grids, or loose packing which is poured into the column, and can be made of plastic, wood, ceramic, or other materials.

6.4 Tray Aerator: Similar to a packed tower, this type of aeration device uses stacked porous shallow trays to distribute the water in thin sheets. Air is generally passed through perpendicularly to the trays.

6.5 Diffused Aeration: An aeration process in which compressed air is introduced into the bottom of a water basin through a two-dimensional matrix of microporous air ports.

6.6 Spray Aerator: An aeration process in which air is introduced into water by rapidly agitating the water surface with a mechanical mixer, causing a spray of water at the surface.

6.7 Membrane Air Stripper: An air stripping process in which the air to water contact is provided in the pores of a microporous hydrophobic gas permeable membrane. Water passes through the lumen of the membrane hollow fibers while air is passed through the membrane air stripper module on the exterior of the membrane fibers.

6.8 Water Loading Rate or Liquid Loading Rate (L): Volume of water entering the air stripper per unit time, normalized by the cross-sectional area of the air stripper. The water loading rate has units of volume per area per time: $m^3/(m^2 \times sec)$ or $ft^3/(ft^2 \times sec)$.

6.9 Air Loading Rate or Gas Loading Rate (G): Volume of air entering the air stripper per unit time, normalized by the cross-sectional area of the air stripper. The air loading rate has units of volume per area per time: $m^3/(m^2 \times sec)$ or $ft^3/(ft^2 \times sec)$.

6.10 Air/Water Ratio (A/W): The ratio of the air loading rate to the water loading rate. The air to water ratio is dimensionless. (A/W = G/L).

6.11 Henry's Law Coefficient (H): Dimensionless ratio of the mass concentration of a given VOC in air to the mass concentration in water present at equilibrium between the two phases.

6.12 Stripping Factor (S): Dimensionless expression which is equal to the product of the air to water ratio and the Henry's Law coefficient of the VOC of interest.

6.13 Removal Efficiency: Percent removal of a contaminant (VOC) of interest.

or,

$$R = [1 - (C_{feed} - C_{fin})/C_{feed}] \times 100\%$$

6.14 Channeling: Flow of water in channels formed along the media surface due to low water flow rate, which causes a reduced area for contact of air and water.

6.15 Flooding: Holdup of water in the air stripper due to high air loading rate.

6.16 Biofouling: Buildup of biological material on the packing material, resulting in increased air pressure drop.

6.17 Scaling: Buildup of precipitated solids on the packing material, resulting in increased air pressure drop.

7.0 BACKGROUND INFORMATION ON AIR STRIPPING

Air stripping for removal of VOCs from water is strictly a mass transfer process. No chemical reaction or transformation of the VOC occurs. Air stripping equipment is designed to provide a large surface area for contact between the water and VOC-free air, allowing VOCs to transfer from the water to the air in response to a concentration gradient between the two phases. Maximum mass transfer will occur in an air stripper that provides the greatest possible interface for contact between the phases, and increases the mass transfer coefficient in the water phase by providing turbulent flow conditions.

Theories of VOC transfer in air stripping are well known (e.g. Dvorak, et al. 1996), especially in packed tower aerators (e.g. Kavanaugh and Trussell, 1980; Ball et al., 1984). Other air stripping equipment, though not as thoroughly studied, can also be well understood using mass transfer theory (e.g. membrane air stripping (Zander et al., 1986); cascade crossflow air stripping (Verma et al., 1994); surface aerators (Parker et al., 1996)).

In all cases two-film theory can be used to describe the resistance to mass transfer encountered by a VOC molecule in transferring from one phase to the other as the sum of the individual resistances to mass transfer in each phase. The overall resistance to mass transfer ($1/K_La$) is given by:

$$1/K_La = 1/k_La + 1/Hk_Ga$$

where K_L is the overall mass transfer rate coefficient based on the water phase driving force, k_L is the water side mass transfer coefficient, and k_G is the gas phase mass transfer coefficient. The term 'a' in each of the above expressions is the interfacial area between water and air per unit volume of the aerator. Each of the mass transfer coefficients, as well as the interfacial area available for mass transfer in a given aerator, are functions of the A/W ratio provided to the aerator.

Design equations are available for the different types of aeration equipment. For the example of packed tower aeration, the depth of tower packing necessary to provide a desired removal efficiency is calculated from a mass balance over a control volume (Hines and Maddox, 1985).

$$\text{Depth} = L/K_La\,[S/(S-1)]\,\ln\{1/S + [(S-1)/S]\,(C_{feed}/C_{fin})\}$$

where, L = water loading rate
S = stripping factor
C_{feed} = mass concentration of the VOC of interest in the feed water
C_{fin} = mass concentration of the VOC of interest in the finished water

Thus in air stripping, removal efficiency is a function of the stripping factor, S, and the overall mass transfer coefficient K_La. More precisely, removal efficiency is a function of the air and water loading rates to the equipment and the Henry's Law coefficient of the VOC of interest.

For a given set of air and water loading rates, verification of a certain removal efficiency for a VOC with a Henry's Law coefficient $H = H_1$, ensures equal or greater removal efficiency for all VOCs with H greater than H_1. Similarly, verification of a certain removal efficiency for a VOC at a given set of air and water loading rates, ensures equal or greater removal efficiency for that VOC at a higher air loading rate and the given water loading rate (assuming flooding does not occur). Finally, verification of a given removal efficiency for a given VOC at a temperature $T = T_1$, ensures equal or greater removal efficiency for that VOC at any T greater than T_1.

For mechanical air stripping equipment such as a spray aerator, verification of removal efficiency for a VOC with a Henry's law coefficient of $H = H_1$, ensures equal or greater removal efficiency for all VOCs with H greater than H_1, and equal or greater removal efficiency of the given VOC at any motor speed greater than that tested.

As each type of air stripping equipment allows calculation of an estimated removal efficiency using design equations, operating conditions and the VOCs to be tested can and should be judiciously chosen to minimize unnecessary testing.

8.0 TASK 1: CHARACTERIZATION OF FEED WATER

8.1 Introduction

This task is needed to document the chemical and microbiological characteristics of the feed water.

8.2 Experimental Objective

The objective of this task is to document the water quality characteristics of the feed water to the air stripping system, including the initial mass concentration of VOCs of interest in the feed water and potentially including the calculated potential for precipitative scaling, and a measured indication of the potential for microbiological fouling.

8.3 Work Plan

This task can be accomplished by using approved analytical measurements obtained from certified third party sources (i.e. United States Geological Society (USGS), EPA, State Laboratories, Municipal Laboratories). The specific parameters needed to characterize the water will depend on the equipment being tested, but information on the following characteristics should be compiled:

- VOCs of interest and their respective mass concentration in the feed water and water temperature.

It is recommended that additional parameters be measured to characterize the water, including:

- Dissolved oxygen, pH and turbidity to establish physical characterization;
- Total Dissolved Solids, Total Alkalinity, Total Hardness, Scaling Potential, Iron, and Manganese to establish inorganic chemical characterization; and
- Heterotrophic Plate Count and Total Sulfur to establish the potential for microbiological fouling.

A brief description of the water source shall be provided to aid in interpretation of feed water characteristics.

Several of the water quality parameters described in this task shall be measured on-site by the NSF-qualified Field Testing Organization. Analysis of the remaining water quality parameters shall be performed by a State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. The methods to be used for measurement of water quality parameters in the field are described in Tables 1 and 2. Where appropriate, the Standard Methods reference numbers and EPA method numbers for water quality parameters are provided for both the field and laboratory analytical procedures.

For the water quality parameters requiring analysis at an off-site laboratory, water samples shall be collected in appropriate containers (containing preservatives as applicable) prepared by the State certified, third-party accredited (e.g. NSF), or EPA accredited laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical lab.

8.4 Analytical Schedule

In many cases, sufficient water quality data may already exist to permit making a determination of the suitability of a water source for use as feed water in an air stripping Verification Testing Program. In the absence of such data, a set of these measurements performed by an approved lab will suffice for this task. Table 1 outlines the required parameters to be measured and the methods to be used for analysis. Table 2 outlines the recommended parameters to be measured and their respective analytical methods.

Table 1
Required Analytical Parameters and Methods

Parameter	Facility	Standard Method[a]	EPA Method[b]
VOCs (specify)	Lab	6210 C	502.2 / 524.2
Temperature	On-Site	2550 B	

Notes:
[a] APHA, AWWA, WEF, 1992 (or later).
[b] EPA Methods Source: EPA Office of Ground and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

Samples of feed waters shall be collected for analysis of indigenous bacterial densities by heterotrophic plate count (HPC). Collected samples shall be placed in a cooler with blue ice to be shipped with an internal cooler temperature of approximately 2-8°C to the State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. Samples shall be processed for analysis by the State certified, third-party accredited (e.g. NSF), or EPA accredited laboratory within 24 hours of collection. The laboratory shall then keep the samples at a temperature of approximately 2-8°C until initiation of analysis. HPC densities will be reported as colony forming units per milliliter (cfu/mL).

Table 2
Recommended Analytical Parameters and Methods

Parameter	Facility	Standard Method[a]	EPA Method[b]
pH	On-Site	4500-H^+	150.1 / 150.2
Turbidity	Lab	2130 B	180.1
Dissolved Oxygen	Lab	4500-O	
Total Dissolved Solids	Lab	2540 C	
Total Alkalinity	Lab	2320 B	
Total Hardness	Lab	2340 C	
Iron	Lab	3113 B	200.7 / 200.8 / 200.9
Manganese	Lab	3113 B	200.7 / 200.8 / 200.9
Total Sulfide	Lab	4500-S^{2-}	
Heterotrophic Plate Count	Lab	9215 B	
Scaling Potential	Calculated	Langlier's Index	

Notes:
[a] APHA, AWWA, WEF, 1992 (or later).
[b] EPA Methods Source: EPA Office of Ground and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

8.5 Evaluation Criteria and Minimum Reporting Requirements

Feed water quality will be evaluated in the context of the Manufacturer's statement of performance capabilities. The feed water should challenge the capabilities of the equipment but should not be beyond the range of water quality suitable for treatment using the equipment specified. The Langelier Index or another index which quantifies the scaling potential for the feed water should be calculated and reported along with the raw data collected as part of this task.

9.0 TASK 2: VERIFICATION TESTING

9.1 Introduction

Package air stripping equipment shall be operated for Verification Testing purposes. VOC removal efficiency by the air stripping equipment will be tested for the stated VOCs of interest.

9.2 Experimental Objectives

The objective of this task is to operate the equipment provided by the Manufacturer and to assess its ability to meet the water quality goals and any other performance characteristics specified by the manufacturer in the statement of performance capabilities.

9.3 Work Plan

This task shall be performed concurrently with Task 3: Operating Conditions and System Performance.

For this task the Manufacturer or Field Testing Organization shall specify the operating conditions to be evaluated in this Verification Testing Plan and shall supply written procedures on the operation and maintenance of the air stripping system. The Field Testing Organization shall specify the air and water loading rates at which the equipment is to be verified, and the VOCs which should be measured as part of the verification testing.

After set-up and shakedown of the air stripping equipment, operation should be established at the air and water loading rates for the condition to be verified. The air stripping equipment shall be operated under these steady state conditions for a minimum of eight hours per operating condition to be verified.

Additional operational conditions may be verified using the same equipment in successive periods as long as the verification period does not extend beyond the time period of coldest operating temperature for verification purposes. For each testing period the air and water loading rates to be tested shall be explicitly stated prior to testing.

This Verification Testing Plan has been designed with the aim of balancing cost of verification with benefits of testing over a wide range of operating conditions. It shall be understood that beyond the operational characteristics specifically tested, air stripping equipment operation which occurs at an air loading rate higher than specifically tested for a given water loading rate shall also constitute a verifiable condition, as long as the condition does not lead to flooding.

Many of the water quality parameters described in this task shall be measured on-site by the NSF-qualified Field Testing Organization. Analysis of the remaining water quality parameters shall be performed by a State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. The methods to be used for measurement of water quality parameters in the field are described in Table 1 with additional recommended parameters in Table 2. Where appropriate, the Standard Methods reference numbers and EPA method numbers for water quality parameters are provided for both the field and laboratory analytical procedures.

For the water quality parameters requiring analysis at an off-site certified or accredited laboratory, water samples shall be collected in appropriate containers (containing preservatives as applicable) prepared by the State certified, third-party accredited (e.g. NSF), or EPA accredited off-site laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical lab.

9.4 Analytical Schedule

Samples shall be collected at least three times per operational condition and at least two hours apart from the feed water and the finished water and analyzed to determine the mass concentration of the VOCs of interest. The temperature of the feed water and finished water shall be measured and documented immediately after samples for VOC analysis are collected. The analytical methods are provided in Table 3.

Table 3
Testing Schedule and Methods for Verification Testing

Parameter	Location	Facility	Method
VOCs (specified)	Feed water	Lab	Standard Methods[a] 6210 C or EPA Method[b] 524
VOCs (specified)	Finished water	Lab	Standard Methods[a] 6210 C or EPA Method[b] 524
Temperature	Feed water	On-Site	Standard Methods 2550 B
Temperature	Finished water	On-Site	Standard Methods 2550 B

Notes:
[a] APHA, AWWA, WEF, 1992 (or later).
[b] EPA Methods Source: EPA Office of Ground and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

9.5 Evaluation Criteria and Minimum Reporting Requirements

The goal of this task is to operate the equipment under steady state conditions at each verifiable operating condition. Data shall be provided to substantiate operation at steady state. The concentration of each VOC of interest in the feed water and the finished water shall be reported for each condition, along with the temperature of the feed and finished water. In addition, all operational data collected shall be reported.

10.0 TASK 3: OPERATING CONDITIONS AND SYSTEM PERFORMANCE

10.1 Introduction

During each condition of Verification Testing, and at least twice during each day, operating conditions shall be documented. This shall include a statement of any pretreatment performed on the feed water, documentation of air pressure drop through the equipment, flow measurements, visual inspection of equipment, and any maintenance activities performed.

10.2 Experimental Objectives

The objective of this task is to accurately and fully document the operating conditions that are applied during treatment and the performance of the air stripping equipment. This task is intended to result in data that describe the operation of the equipment and data that can be used to develop cost estimates for operation of the equipment.

10.3 Work Plan

This task shall be performed concurrently with Task 2: Verification Testing.

Measurement of feed water flow rate, air flow rate, and air pressure entering the air stripper shall be performed at a minimum of two times per day. For packed tower and tray aerator systems, air pressure exiting the system shall also be measured two times per day, within 15 minutes of measurement of the influent air pressure.

In an attempt to calculate costs for operation of air stripping equipment, power costs for operation of the equipment shall also be closely monitored and recorded by the Field Testing Organization during the testing period(s). Power usage shall be estimated by the following requirements: pumping requirements, size of pumps, nameplate voltage, current draw, power factor, motor power usage for fans or mixers, etc.

10.4 Evaluation Criteria and Minimum Reporting Requirements

Where applicable, the data developed from this task will be compared to statement of performance capabilities. If no relevant statement of performance capability exists, results of operating and performance data will be tabulated for inclusion in the Verification Report.

11.0 TASK 4: FINISHED WATER QUALITY

11.1 Introduction

Water quality data shall be collected for the finished water as was performed for the feed water and as shown in Table 1. At a minimum, the required sampling shown in Table 1 shall be observed by the Field Testing Organization on behalf of the Manufacturer. Recommended tests from Table 2 may also be included. Water quality goals and target removal goals for the air stripping equipment shall be recorded in the Field Operations Document.

11.2 Experimental Objectives

The objective of this task is to assess the ability of the air stripping equipment to meet the water quality goals specified by the Manufacturer and to identify any potential adverse effect on the water quality.

11.3 Work Plan

Several of the water quality parameters described in this task shall be measured on-site by the NSF-qualified Field Testing Organization (refer to Table 2). Analysis of the remaining water quality parameters shall be performed by a State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. The methods to be used for measurement of water quality parameters in the field are described in Table 1. Where appropriate, the Standard Methods reference numbers and EPA method numbers for water quality parameters are provided for both the field and laboratory analytical procedures.

For the water quality parameters requiring analysis at an off-site certified or accredited laboratory, water samples shall be collected in appropriate containers (containing preservatives as applicable) prepared by the State certified, third-party accredited (e.g. NSF), or EPA accredited off-site laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical lab.

11.4 Analytical Schedule

At least once in each verification test the finished water shall be characterized by measurement of the following water quality parameters (as indicated also in Table 2). The specific parameters needed to characterize the water will depend on the equipment being tested, but information on the following characteristics are also recommended for compilation:

- Dissolved oxygen, pH and turbidity to establish any changes in physical characterization relative to the feed water;
- Total Dissolved Solids, Total Alkalinity, Total Hardness, Corrosivity, Iron, and Manganese to establish mass balances on the inorganic parameters; and
- Heterotrophic Plate Count and Total Sulfide to indicate the likelihood of biological fouling.

Additional sampling and data collection may be performed at the discretion of the Field Testing Organization. Sample collection frequency and protocol shall be defined by the Field Testing Organization in the Field Operations Document.

Samples of feed waters shall be collected for analysis of indigenous bacterial densities by heterotrophic plate count (HPC). Collected samples shall be placed in a cooler with blue ice to be shipped with an internal cooler temperature of approximately 2-8°C to the State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. Samples shall be processed for analysis by the State certified, third-party accredited (e.g. NSF), or EPA accredited laboratory within 24 hours of collection. The laboratory shall then keep the samples at a temperature of approximately 2-8°C until initiation of analysis. HPC densities will be reported as colony forming units per milliliter (cfu/mL).

11.5 Evaluation Criteria and Minimum Reporting Requirements

Where applicable, the data from this task will be utilized to determine if scaling or biofouling has occurred in the air stripping equipment, and as feasible perform a mass balance to determine the extent of that fouling. Any loss of inorganic material shall be interpreted as scaling and increase in biological material shall be interpreted as fouling and must be reported in the Verification Report.

12.0 TASK 5:DATA MANAGEMENT

12.1 Introduction

The data management system used in the verification testing program shall involve the use of computer spreadsheets and manual recording of operational parameters for the air stripping equipment on a daily basis.

12.2 Experimental Objectives

The objective of this task is to establish a viable structure for the recording and transmission of field testing data such that the Field Testing Organization provides sufficient and reliable operational data to the NSF for verification purposes.

12.3 Work Plan

The following protocol has been developed for data handling and data verification by the Field Testing Organization. Where possible, a Supervisory Control and Data Acquisition (SCADA) system should be used for automatic entry of testing data into computer databases. Specific parcels of the computer databases for operational and water quality parameters should then be downloaded by manual importation into spreadsheet software. These specific database parcels shall be identified based upon discrete time spans and monitoring parameters. In spreadsheet form, the data shall be manipulated into a convenient framework to allow analysis of equipment operation. At a minimum, backup of the computer databases to diskette should be performed on a weekly basis.

In the case when a SCADA system is not available, field testing operators shall record data and calculations by hand in laboratory notebooks. (Daily measurements shall be recorded on specially-prepared data log sheets as appropriate.) The laboratory notebook shall provide carbon copies of each page. The original notebooks shall be stored on-site; the carbon copy sheets shall be forwarded to the project engineer of the Field Testing Organization at least once per week during each testing period. This protocol will not only ease referencing the original data, but offer protection of the original record of results. Pilot operating logs shall include a description of the air stripping equipment (description of test runs, names of visitors, description of any problems or issues, etc.); such descriptions shall be provided in addition to experimental calculations and other items.

The database for the project shall be set up in the form of custom-designed spreadsheets. The spreadsheets shall be capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets shall be entered into the appropriate spreadsheet. Data entry shall be conducted on-site by the designated field testing operators. All recorded calculations shall also be checked at this time. Following data entry, the spreadsheet shall be printed out and the print-out shall be checked against the handwritten data sheet. Any corrections shall be noted on the hard-copies and corrected on magnetic storage (e.g. disk), and then a corrected version of the spreadsheet shall be printed out. Each step of the verification process shall be initialed by the field testing operator or engineer performing the entry or verification step.

Each experiment shall be assigned a run number which will then be tied to the data from that experiment through each step of data entry and analysis. As samples are collected and sent to State certified, third-party accredited (e.g. NSF), or EPA accredited laboratories, the data shall be tracked by use of the same system of run numbers. Data from the outside laboratories shall be received and reviewed by the field testing operator. These data shall be entered into the data spreadsheets, corrected, and verified in the same manner as the field data.

13.0 TASK 6: QUALITY ASSURANCE/QUALITY CONTROL

13.1 Introduction

Quality assurance and quality control of the operation of the air stripping equipment and the measured water quality parameters shall be maintained during the verification testing program.

13.2 Experimental Objectives

The objective of this task is to maintain strict QA/QC methods and procedures during the Equipment Verification Testing Program. Maintenance of strict QA/QC procedures is important, in that if a question arises when analyzing or interpreting data collected for a given experiment, it will be possible to verify exact conditions at the time of testing.

13.3 Work Plan

Equipment flow rates and associated signals should be documented and recorded on a routine basis. A routine daily visual check during testing shall be established to verify that each piece of equipment or instrumentation is operating properly. Air and water flow rates shall be measured and documented. In-line monitoring equipment such as flowmeters, etc. shall be checked to confirm that the readout matches with the actual measurement (i.e. flow rate) and that the signal being recorded is correct. The items listed are in addition to any specified checks outlined in the analytical methods.

13.4 On-Site Analytical Methods

The analytical methods utilized in this study for on-site monitoring of feed water and filtrate water quality are described in the section below. Use of either bench-top or in-line field analytical equipment will be acceptable for the verification testing; however, in-line equipment is recommended for ease of operation. Use of in-line equipment is also preferable because it limits the introduction of error and the variability of analytical results generated by inconsistent sampling techniques.

13.4.1 Temperature

Readings for temperature shall be conducted in accordance with Standard Methods 2550. Raw water temperatures shall be obtained at least once daily. The thermometer shall have a scale marked for every 0.1 ^{o}C, as a minimum, and should be calibrated weekly against a precision thermometer certified by the National Institute of Standards and Technology (NIST). (A thermometer having a range of -1 ^{o}C to +51 ^{o}C, subdivided in 0.1 ^{o}C increments would be appropriate for this work.)

13.4.2 pH (Optional)

Analyses for pH shall be performed according to Standard Method 4500-H^+. A 2 point calibration of the pH meter used in this study shall be performed once per day when the instrument is in use. Certified pH buffers in the expected range shall be used. The pH probe shall be stored in the appropriate solution defined in the instrument manual. Transport of carbon dioxide can confound pH measurements in poorly buffered waters. If this is a problem, measurement of pH in a confined vessel is recommended.

13.4.3 Turbidity (Optional)

Turbidity analyses shall be performed in accordance with Standard Method 2130 with a bench-top turbidimeter. (An in-line turbidimeter is acceptable, but unnecessary for this task.) The turbidimeter shall be calibrated within the expected range of sample measurements at the beginning of verification testing and on a weekly basis thereafter using primary turbidity standards of 0.1, 0.5 and 3.0 NTU. The turbidimeter shall be recalibrated after being shut off and re-started.

The method of collecting grab samples will consist of running a slow, steady stream from the sample tap, triple-rinsing a dedicated sample beaker in this stream, allowing the sample to flow down the side of the beaker to minimize bubble entrainment, double-rinsing the sample vial with the sample, carefully pouring from the beaker down the side of the sample vial, wiping the sample vial clean, inserting the sample vial into the turbidimeter, and recording the measured turbidity. For the case of cold water samples which cause the vial to fog, allow the vial to warm slightly by submersing partially into a warm water bath for approximately thirty seconds.

13.4.4 Dissolved Oxygen (Optional)

Dissolved oxygen analyses shall be performed in accordance with Standard Method 4500-O with a field dissolved oxygen meter or a field titration. Calibrate either method as described in Standard Methods (APHA, AWWA, WEF, 1992).

Avoid entraining or dissolving atmospheric oxygen during sampling. In sampling from a line under pressure, attach a glass or rubber tube to the tap and extend to the bottom of the sample bottle. Let the bottle overflow two or three times its volume and stopper the bottle.

13.5 Chemical and Biological Samples Shipped Off-Site for Analysis

13.5.1 VOCs

Samples for measurement of VOC concentrations shall be collected headspace-free in 25- or 40-mL glass bottles equipped with a screw cap with a hole in the center and TFE-lined silicone septa supplied by the State certified, third-party accredited (e.g. NSF), or EPA accredited laboratory. Samples shall be collected in duplicate, stored at 4 ^{o}C in an atmosphere free of organic solvent vapors, and shipped at 4 ^{o}C to the analytical laboratory. Field blanks shall be collected with the samples and subjected to storage and shipping as performed for the analytical samples. Analysis shall occur within 14 days of sampling.

13.5.2 Chemical Analysis: Total Dissolved Solids, Alkalinity, and Hardness (Optional Parameters)

Samples shall be collected headspace-free in polyethylene or borosilicate glass bottles and capped tightly. Store and ship at 4 ^{o}C. Analyze as soon as possible and in no case store samples more than 7 days. Bring samples to room temperature prior to analysis.

13.5.3 Chemical Analysis: Iron and Manganese (Optional Parameters)

Samples shall be collected in acid-rinsed polypropylene or linear polyethylene containers supplied by the State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. Preserve samples immediately after sampling with concentrated high-purity nitric acid to a pH less than 2. Usually 1.5 mL concentrated HNO_3 per liter of sample is sufficient. Store and ship at 4 ^{o}C, and analyze as soon as possible, but within 6 months of sampling.

13.5.4 Chemical Analysis: Total Sulfide (Optional)

Samples shall be collected with minimum aeration in polypropylene or glass bottles containing zinc acetate solution provided by the State certified, third-party accredited (e.g. NSF), or EPA accredited laboratory. Fill the bottle completely and add NaOH dropwise to a pH greater than 9. Store and ship at 4 ^{o}C, and analyze as soon as possible, but within 28 days of sampling.

13.5.5 Microbial Analysis: Heterotrophic Plate Count (Optional)

Microbiological samples shall be collected in carefully cleaned and sterilized bottles or bags supplied by the State certified, third-party accredited (e.g. NSF), or EPA accredited analytical laboratory. Analyze samples as soon as possible, but within 24 hours of sampling. Hold and ship samples at or below 4 ^{o}C, but do not freeze.

14.0 TASK 7: EFFECT OF SCALING AND BIOFOULING (RECOMMENDED)

14.1 Introduction

Long-term performance of the air stripping equipment involving the effect of scaling and/or biofouling on the VOC removal efficiency is recommended to be determined in a 30-day continuous operation during the warmest season of the year.

14.2 Experimental Objectives

The objective of this task is to quantify the reduction of VOC removal efficiency over a continuous 30-day operating period for a given feed water.

14.3 Work Plan

This task shall be performed concurrently with Task 3: Operating Conditions and System Performance.

For this task the Manufacturer or Field Testing Organization shall specify the operating condition to be utilized for a 30-day continuous operation during the warmest season of the year. The Field Testing Organization shall specify the air and water loading rates at which the equipment is to be verified, and the VOCs which should be measured as part of the verification testing.

After set-up and shakedown of the air stripping equipment, operation should be established at the air and water loading rates for the condition to be verified. The air stripping equipment shall be operated under these steady state conditions for a minimum of 30 days.

Analysis of the concentration of VOCs in the feed water and the finished water shall be performed by a state certified, third-party accredited (e.g. NSF), or EPA accredited laboratory. Water samples shall be collected in appropriate containers prepared by the state certified, third-party accredited (e.g. NSF), or EPA accredited off-site laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical lab.

14.4 Analytical Schedule

Samples shall be collected at least every third day from the feed water and the finished water and analyzed to determine the mass concentration of the VOCs of interest.

14.5 Evaluation Criteria and Minimum Reporting Requirements

The goal of this task is to quantify the VOC removal efficiency over a longer operation period. Data should be provided to verify operation for at least 30 days. The concentration of each VOC of interest in the feed water and the finished water shall be reported for at least every third day**,** along with the temperature of the feed and finished water. Removal efficiency for each VOC shall be calculated for each set of samples. In addition, all operational data collected shall be reported.

15.0 OPERATION AND MAINTENANCE MANUAL CRITERIA - AIR STRIPPING EQUIPMENT

The Field Testing Organization shall obtain the Manufacturer-supplied Operations and Maintenance (O&M) Manual to evaluate the instructions and procedures for their applicability during the verification testing period. The following are recommendations for criteria for O&M Manuals for package plants employing air stripping for removal of VOCs.

15.1 Maintenance

The Manufacturer should provide readily understood information on the recommended or required maintenance schedule for each piece of operating equipment such as:

- pumps
- blowers
- valves
- motors
- instruments, such as an in-line turbidimeter
- flow measurement devices

The manufacturer should provide readily understood information on the recommended or required maintenance of non-mechanical or non-electrical equipment such as:

- tanks and basins
- tower materials
- tower packing or tray materials
- membrane modules.

15.2 Operation

The Manufacturer should provide readily understood recommendations for procedures related to proper operation of the package plant equipment. Among the operating aspects that should be discussed are:

- Procedures for setting and measuring air and water flow rates
- Proper cleaning procedures for all equipment provided
- Proper operation of any pretreatment equipment deemed necessary.

16.0 REFERENCES

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